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INFORMATIVE VALUE OF BIOMETRIC INDICES OF IRIS, SCLERA AND CORNEA IN PRIMARY OPEN-ANGLE GLAUCOMA DIAGNOSIS

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✧ ***Aim:*** to study the thickness of cornea, iris and scleral tissue, to determine its asymmetry between fellow eyes in healthy subjects and in patients with primary glaucoma. To determine the relationship between changes in biomechanical properties of the cornea and sclera and iris thickness in healthy subjects and in patients with primary glaucoma. ***Materials and methods.*** 10 patients (20 eyes) with primary glaucoma were examined. The control group consisted of 10 people (20 eyes). In all patients ultrasound biomicroscopy (Humphrey Instruments (USA), Model 840) was performed. ***Results and discussion.*** The article presents a study of the corneoscleral and iris tissue thickness in primary glaucoma, as well as the increase pattern of the revealed asymmetry in corneoscleral and iris tissue thickness from normal state to glaucoma. A positive direct correlation between the indices of cornea, sclera, and iris thickness in the primary glaucoma group and between biometric parameters of sclera and iris and the of corneal hysteresis value in primary open-angle glaucoma.

✧ ***Keywords:*** primary glaucoma; ultrasound biomicroscopy; scleral thickness; corneal thickness; iris thickness.

ИНФОРМАТИВНОСТЬ БИОМЕТРИЧЕСКИХ ПОКАЗАТЕЛЕЙ РАДУЖКИ, СКЛЕРЫ И РОГОВИЦЫ В ДИАГНОСТИКЕ ПЕРВИЧНОЙ ОТКРЫТОУГОЛЬНОЙ ГЛАУКОМЫ

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✧ ***Цель исследования.*** Изучить толщину роговичной, склеральной и радужной ткани, определить её межокулярную асимметрию в норме и при первичной глаукоме. Определить взаимосвязь изменений биомеханических свойств роговицы и толщины склеры и радужки в норме и при первичной глаукоме. ***Материалы и методы.*** Обследовано 10 пациентов (20 глаз) с первичной глаукомой. Контрольную группу составили 10 человек (20 глаз). Выполнялась ультразвуковая биомикроскопия на аппарате фирмы Humphrey Instruments (USA), модель 840. ***Результаты и обсуждение.*** Представлено исследование толщины ткани корнеосклеральной и радужной оболочек при первичной глаукоме, а также выявлена закономерность нарастания межокулярной асимметрии толщины этих тканей от состояния нормы к патологии, при глаукоме. Обнаружена положительная прямая корреляционная связь между показателями толщины роговицы, склеры и радужной оболочки в группе с первичной глаукомой и между биометрическими показателями склеры и радужки с величиной корнеального гистерезиса при первичной открытоугольной глаукоме.

✧ ***Ключевые слова:*** первичная глаукома; ультразвуковая биомикроскопия; толщина склеры; толщина роговицы; толщина радужки.

INTRODUCTION

Despite significant advances in diagnosis and treatment, glaucoma remains one of the most severe ocular diseases, often leading to visual impairments and disabilities and blindness [5]. Current high-tech methodologies, such as ultrasonic biomicroscopy (UBM) and the ocular response analyzer (ORA), provide additional diagnostic options for ocular disorders. ORA allows for the assessment of biomechanical characteristics of the cornea, including estimation of viscoelastic properties of the cornea by measuring corneal hysteresis (CH).

UBM is now firmly established in clinical practice as a basic and informative diagnostic method for various disorders of the anterior segment of the eye. The assessment of the anterior chamber angle [3, 10, 14] and the anterior and posterior eye chambers using UBM allowed for the development of different approaches for the diagnosis and treatment of various glaucomas [10]. Increasing clinician interest in these diagnostic methods requires the understanding of general concepts about the ocular structures that can be visualized, normal limits, and indicators of pathology. In addition to the ability to visualize the anterior chamber angle, particular attention should be paid to the utility of UBM for measuring the corneoscleral and iris thickness. Only few studies have evaluated the corneoscleral and iris thickness in patients with primary open-angle glaucoma (POAG) using UBM. In POAG, the interocular asymmetry of various parameters is an important diagnostic criterion [9, 11]; therefore, it is crucial to measure UBM parameters in both eyes to evaluate the pathogenic role of corneoscleral changes in POAG for glaucoma diagnosis and prognosis.

Well-known morphological and clinical signs [1, 2, 4, 6–8] associated with the loss of scleral elasticity are a clear indication for the involvement of the sclera in the pathology of primary glaucoma. Moreover, the common origin and similar morphology of the cornea, iris, and sclera suggest that the assessment of corneal biomechanical properties can provide additional information on both scleral elasticity and iris changes in the pathogenesis of glaucoma.

Here, we aimed to evaluate the corneoscleral and iris thickness, assess the interocular asymmetry and range of values in UBM parameters, and estimate the correlation between corneal biomechanical properties and cornea and iris thickness in healthy individuals and patients with POAG.

MATERIALS AND METHODS

The study included 20 patients (40 eyes) who were divided into two groups: the experimental group of 10 patients (20 eyes) with POAG (as diagnosed by standard methods) and a control group of 10 individuals (20 eyes) without ocular disorders and normal intraocular pressure (IOP). Patients who underwent ocular surgery or had eye trauma, uveitis, pseudoexfoliation syndrome, or clinically diagnosed immature cataract were excluded because these conditions can change the anatomical and topographic characteristics of the eye. The mean age of patients with POAG was 71 (range: 70–72) years, whereas that of controls was 73 (range: 70–77) years; the difference between the groups was non-significant ($p > 0.05$). POAG was diagnosed using standard methods.

UBM was performed using a Humphrey UBM 840 system (Humphrey Instruments, Inc., USA) with a frequency of 50 MHz to evaluate the anterior segment of the eye. Eyes were assessed along the 3-, 6-, 9-, and 12-o'clock meridians with a sensor aligned perpendicular to the structures examined (cornea, anterior chamber angle, iris, iris root, corneoscleral spur, and sclera). All measurements were performed using the methods of Pavlin et al. [12, 13]. The following parameters were evaluated: corneal thickness 4,000 μm from the calcarine sulcus, scleral thickness at the calcarine sulcus measured perpendicular to the scleral surface, iris thickness at the iris root and 500, 1,000, and 1,500 μm from the root. The interocular asymmetry of all examined structures was also assessed. In healthy individuals, interocular asymmetry was calculated by subtracting the measurements of one eye from those of the other eye. In patients with POAG, the interocular asymmetry was calculated by subtracting the values for the worse eye from those of the better eye. The biomechanical properties of the cornea were estimated by measuring CH using ORA (Reichert, USA).

Descriptive statistical methods were used to analyze the results. Medians (Me), first and third quartiles (Q1 and Q3), and interquartile ranges were calculated.

RESULTS AND DISCUSSION

Measurements of corneal, scleral, and iris thickness in healthy individuals and patients with POAG using UBM

UBM indicated a significantly reduced corneal thickness in patients with POAG compared with controls: 0.57 mm (Q1–Q3: 0.54–0.60 mm; range:

0.51–0.66 mm) vs 0.62 mm (Q1–Q3: 0.60–0.63 mm; range: 0.58–0.67 mm) ($p < 0.01$) (Table 1).

A significantly reduced scleral thickness was also observed in patients with glaucoma compared with healthy individuals ($p < 0.001$). The median scleral thickness in controls was 1.32 mm (Q1–Q3: 1.29–1.35 mm; range: 1.26–1.48 mm), whereas that in patients with POAG was 1.14 mm (Q1–Q3: 1.02–1.26 mm; range: 0.80–1.48 mm). The reduction in the corneal and scleral thickness suggests the involvement of the corneoscleral membrane in the pathogenesis of POAG. Scleral changes in patients with POAG have been confirmed in earlier studies using other methodologies, including Friedenwald's differential tonometry and the dynamic rehydration method [8]. Assuming that other structures in the anterior segment of the eye, particularly the iris, may also be involved in the pathogenesis of POAG, the assessment of iris thickness is important for patients with POAG. Using UBM, an increase in iris thickness from the root to the pupil margin was observed in both the groups, which is associated with structural and functional characteristics of the iris; however, patients with POAG had a decrease in the iris thickness compared with the healthy individuals (Table 1). The median iris thickness at the iris root was 0.39 mm (Q1–Q3: 0.38–0.40 mm; range: 0.31–0.44 mm) in healthy controls vs 0.34 mm (Q1–Q3: 0.30–0.37 mm; range: 0.20–0.41 mm) in patients with POAG ($p < 0.001$). The median iris thickness at 500 μm from the iris root was significantly lower in patients with POAG than in controls: 0.38 mm (Q1–Q3: 0.33–0.42 mm; range: 0.24–0.49 mm) vs 0.44 mm (Q1–Q3: 0.42–0.46 mm; range: 0.37–0.56 mm) ($p < 0.001$). Similar trends were observed for iris thickness measured at other points. In glaucoma patients, the median iris thickness at 1,000 μm from the iris root was 0.40 mm (Q1–Q3: 0.38–0.44 mm; range: 0.41–0.51 mm); whereas, in controls, it was 0.48 mm (Q1–Q3: 0.46–0.49 mm; range: 0.41–0.59 mm) ($p < 0.001$). The median iris thickness at 1,500 μm from the iris root was 0.43 mm (Q1–Q3: 0.39–0.46 mm; range: 0.31–0.51 mm) in patients with POAG and 0.50 mm (Q1–Q3: 0.48–0.52 mm; range: 0.44–0.62 mm) in healthy individuals ($p < 0.001$). Our findings suggest a significant impact of glaucoma on the iris, particularly its thickness. The negative effects of glaucoma on the biomechanical properties of the iris can result in the loss of iris elasticity due to tissue degeneration.

The wide ranges of corneal, scleral, and iris thickness in both groups prevents the drawing of unambiguous conclusions about the clinical significance of these parameters for each individual patient; nevertheless, this problem can be addressed by calculating the interocular asymmetry of these parameters in each patient.

Table 1

Biometric parameters of the sclera and iris in healthy individuals and patients with primary open-angle glaucoma, Me (Q1–Q3)

Таблица 1

Биометрические параметры склеры и радужки в норме и при первичной открытоугольной глаукоме, Me ($Q_{25\,\%}$ – $Q_{75\,\%}$)

Biometric parameter	Healthy individuals	Patients with primary open-angle glaucoma
Corneal thickness 4,000 μm from the calcarine sulcus, mm	0.66 (0.60–0.63)	0.57 (0.54–0.60)[1]
Scleral thickness, mm	1.32 (1.29–1.350)	1.14 (1.02–1.26)[2]
Iris thickness at the iris root, mm	0.39 (0.38–0.40)	0.34 (0.30–0.37)[2]
Iris thickness at 500 μm from the iris root, mm	0.44 (0.42–0.46)	0.38 (0.33–0.42)[2]
Iris thickness at 1,000 μm from the iris root, mm	0.48 (0.46–0.49)	0.40 (0.38–0.4) [2]
Iris thickness at 1,500 μm from the iris root, mm	0.50 (0.48–0.52)	0.43 (0.39–0.46)[2]

Note: [1] $p < 0.01$ for comparison of corneal, scleral, and iris thickness at various points between healthy individuals and patients with primary open-angle glaucoma; [2] $p < 0.001$ for comparison of corneal, scleral, and iris thickness at various points between healthy individuals and patients with primary open-angle glaucoma; Me = median; Q1–Q3 = first and third quartiles

Interocular asymmetry in the corneal, scleral, and iris thickness in healthy individuals and patients with POAG

Patients with POAG had significantly higher interocular asymmetry in the corneal thickness than the healthy individuals: 0.05 mm (Q1–Q3: 0.03–0.06 mm) vs 0.02 mm (Q1–Q3: 0.01–0.03 mm) ($p < 0.001$). The interocular asymmetry in the scleral thickness was 0.19 mm (Q1–Q3: 0.05–0.22 mm) in patients with glaucoma and 0.02 (Q1–Q3: 0.01–0.02 mm) in controls ($p < 0.001$). It appears that minor interocular asymmetry in corneal and scleral thickness is normal (Table 2). Patients with POAG have pronounced interocular asymmetry, which is probably associated with an asymmetric pathological process, when the corneal/scleral thickness is lesser in the worse eye and higher in the better eye.

In the healthy controls, the degree of interocular asymmetry in the iris thickness did not exceed 0.02 mm, whereas patients with POAG demonstrated a threefold increase in the interocular asymmetry in the iris thickness (≥0.06 mm). The values for interocular asymmetry did not vary significantly depending on the site of measurement, suggesting similar pathological changes in all areas of the iris.

Results of this study suggest that minor interocular asymmetry of the corneal, scleral, and iris thickness is a normal physiological phenomenon; however, more pronounced interocular asymmetry (>0.04 mm in corneal thickness, >0.1 mm in scleral thickness, and >0.05 mm in iris thickness) is beyond the normal range. Interocular asymmetry in the corneal, scleral, and iris thickness is significantly higher in patients with POAG than in normal individuals that can be attributed to the destruction of these tissues in the pathogenesis of glaucoma.

Correlation between biometric parameters and corneal biomechanical properties

Spearman correlation analysis demonstrated a positive correlation between the corneal and scleral thickness and scleral and iris thickness (at all four measurement points) in patients with POAG (Table 3). The strongest correlation was found between the corneal and scleral thickness ($R = 0.55$; $p < 0.01$), which is to be expected since the cornea and sclera can be considered as parts of the corneoscleral membrane. A moderate positive correlation was observed between the scleral and iris thickness at various measurement points (Table 3). These findings suggest that the cornea, sclera, and iris can be considered as an integrated global connective structure with equal vulnerability to glaucoma.

Spearman correlation coefficients for the biometric parameters of the cornea, sclera, iris, and CH are shown in Table 4. No correlation was found between CH and

Table 2

Interocular asymmetry in biometric parameters of the cornea, sclera, and iris in healthy individuals and patients with primary open-angle glaucoma eyes, Me (Q1–Q3)

Таблица 2

Межокулярная асимметрия биометрических параметров роговицы, склеры и радужки парных глаз в норме и при первичной открытоугольной глаукоме, Me ($Q_{25\,\%}$ – $Q_{75\,\%}$)

Asymmetry in biometric parameter	Healthy individuals	Patients with primary open-angle glaucoma
Asymmetry in the corneal thickness, mm	0.02 (0.01–0.03)	0.05[1] (0.03–0.06)
Asymmetry in the scleral thickness, mm	0.02 (0.01–0.02)	0.19[1] (0.05–0.22)
Asymmetry in the iris thickness at the iris root, mm	0.02 (0.01–0.02)	0.06[1] (0.04–0.08)
Asymmetry in the iris thickness at 500 μm from the iris root, mm	0.02 (0.02–0.02)	0.07[1] (0.02–0.10)
Asymmetry in the iris thickness at 1,000 μm from the iris root, mm	0.02 (0.01–0.02)	0.06[1] (0.02–0.08)
Asymmetry in the iris thickness at 1,500 μm from the iris root, mm	0.02 (0.01–0.03)	0.06[1] (0.02–0.08)

Note: [1]$p < 0{,}001$ for comparison of healthy individuals and patients with primary open-angle glaucoma ; Me = median; Q1–Q3 = first and third quartiles

corneal thickness in patients with glaucoma; however, there was a moderate positive correlation between CH and scleral thickness ($R = 0.48$, $p < 0.05$). A slightly weaker correlation ($R = 0.36$) was observed between CH and iris thickness at the iris root and at 500 μm from the iris root ($p = 0.057$ and 0.052, respectively). The strongest correlation was seen between CH and iris thickness at 1,000 μm and 1,500 μm from the iris root ($R = 0.44$, $p < 0.05$ and $R = 0.48$, $p < 0.01$, respectively).

The direct correlation between parameters reflecting the status of the connective structures in the anterior segment of the eye (cornea, sclera, and iris) confirms the simultaneous loss of their properties in glaucoma.

CONCLUSION

In this study, patients with POAG demonstrated reduced corneal, scleral, and iris thickness compared with normal controls. A positive correlation was found between the thickness of the cornea, sclera, and iris in patients with glaucoma. There was also a positive correlation found between the biometric parameters of the sclera and iris and the degree of CH in POAG. Minor interocular asymmetry in corneal (< 0.04 mm), scleral (< 0.1 mm), and iris (< 0.05) thickness is a normal physiological phenomenon, whereas more pronounced interocular asymmetry is beyond the normal range and is useful as a diagnostic criterion for POAG.

Table 3

Spearman rank correlation analysis of the corneal, scleral, and iris thickness in patients with primary open-angle glaucoma

Таблица 3

Корреляционный анализ по Спирмену биометрических показателей толщины роговицы, склеры и радужной оболочки в группе с первичной открытоугольной глаукомой по данным ультразвуковой биомикроскопии

Biometric parameter	*R*	*P*
Corneal and scleral thickness	0.55	< 0.01
Scleral and iris thickness at the iris root	0.27	< 0.01
Scleral and iris thickness at 500 μm from the iris root	0.26	0.057
Scleral and iris thickness at 1,000 μm from the iris root	0.23	0.052
Scleral and iris thickness at 1,500 μm from the iris root	0.33	< 0.01

Table 4

Spearman rank correlation analysis of the biometric parameters of the sclera and iris and corneal hysteresis in patients with primary open-angle glaucoma

Таблица 4

Корреляционный анализ по Спирмену биометрических показателей склеры и радужки, величины корнеального гистерезиса при первичной открытоугольной глаукоме по данным ультразвуковой биомикроскопии и анализ биомеханических свойств роговицы

Biometric parameter	*R*	*P*
Corneal hysteresis and scleral thickness	0.48	< 0.05
Corneal hysteresis and iris thickness at the iris root	0.36	0.057
Corneal hysteresis and iris thickness at 500 μm from the iris root	0.36	0.052
Corneal hysteresis and iris thickness at 1,000 μm from the iris root	0.44	< 0.05
Corneal hysteresis and iris thickness at 1,500 μm from the iris root	0.48	< 0.01

Additional information:

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Authors' contributions:

V.V. Strakhov developed the research concept and performed final editing of the manuscript.

V.V. Alekseev developed the study design, analyzed the data, performed stylistic and grammatical editing of the manuscript, and submitted the manuscript.

Al-Mrrani Abdulgavi Mohamed Ali performed data collection (corneal hysteresis) and analysis and drafted the manuscript.

A.A. Popova performed data collection (ultrasonic biomicroscopy).

O.N. Klimova performed data collection (standard ophthalmological examination).

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